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The Prevalence of Failures, Mishaps, and Iatrogenic Errors for Restored Endodontically Treated Teeth

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Abstract: ***Introduction:** Restoration of endodontically treated teeth with post and core adds retentive features to the coronal restoration. The survival of these teeth depends on many factors, including the remaining tooth structure, the quality of root canal treatment, post space preparation and placement, and the timing of extra-coronal restoration. Aim: This study assessed the prevalence of failures, mishaps, and iatrogenic errors during post space preparation, post placement, or after final coronal restoration. Materials and Method: A cross-sectional study was conducted in several private dental clinics in Benghazi, Libya. A total of 300 root canal treated teeth restored with posts and cores were examined clinically and radiographically to evaluate the quality of these restored teeth. Results: Only 23.7% showed post-cores with ideal criteria. Most of the inserted posts were less than 2/3 of the root length and had a diameter equal to one-third of the root width. Only 33% of the teeth had between 3-5mm of gutta percha (GP) as an apical seal. Regarding the failure types, the most common type was due to endodontic reasons (33%), whereas the least one was root fracture only (1%). Conclusion: The study showed a high prevalence of post-core failures and mishaps. Education and training for dental professionals on proper post selection and placement techniques are needed to improve prosthetic and endodontic practices.*

Keywords: Post and core, Post failure, Mishaps, Endodontic failure, Root perforation

1.Introduction

One of the most difficult dental procedures is endodontic treatment. For the dentist, every tooth may present different challenges. A crucial component of dental practice is the restoration of endodontically treated teeth, which involves a variety of treatment options with differing degrees of complexity. This becomes more difficult when there is a substantial loss of coronal tooth structure [1]. The appropriate post-endodontic treatment should be chosen based on the amount of residual structure, the tooth's position in the arch, and the functional and aesthetic requirements [2]. Because inadequate restorative therapy is the main cause of its failure [3].

Tooth extraction is often required due to irreparable vertical root fractures caused by restorative failure [4]. Before the final restoration can be finished, endodontically treated teeth are frequently rebuilt, especially when the remaining coronal tooth structure is insufficient to provide retention and resistance for the restoration [5]. When there is little remaining tooth structure, a crown is usually held in place by a core and subsequently held in place by a post. A post and core are commonly made using two basically different procedures: first, a post and core are cast as one piece, and second, a prefabricated post with an instantaneous core made of composite or amalgam [6]. A post can be made from a wide range of materials. They were initially made of alloys of precious metals or stainless steel. Posts made of titanium alloys later arisen. Recent developments in dental materials and adhesive dentistry have led to an increase in the popularity of posts made of ceramic or fiber-reinforced resin composite. Specifically, the glass fiber and zirconium dioxide-reinforced posts offer a very esthetic outcome in addition to a reliable attachment to the hard dental tissues [7].

The physical and mechanical properties of materials used for pulpless tooth rehabilitation influence the biomechanical behavior of the tooth/post/restoration set, potentially altering clinical lifespan. The elastic modulus of the materials used to manufacture posts is critical since it directly affects the biomechanical behavior of restorations. Stiffer posts improve retention and consistent stress distributions in the root canal, but less rigid posts might bend under high loads, resulting in post fractures. More flexible posts weaken the cement layer, which promotes secondary caries or canal reinfection [8].

According to Alharbi et al. [9], glass-fiber posts could be repaired, but metallic posts were more likely to fail catastrophically. FED Figueiredo et al [10]. found no significant differences in root fracture incidence between metal and fiber posts but a higher incidence of non-catastrophic failures for fiber post-restored roots. The correct order of the treatment plan and the precision of every step completed before post placement are essential for the success of post and core procedures [11]. Taking periapical radiographs (PAs) before, during, and after post-cementation is one of the reliable ways to assess the post-placement process [12]. The longevity of dental posts is influenced by a number of factors, including appropriate obturation and filling, a satisfactory apical seal, and the lack of radiographic and clinical symptoms [13].

Post preparation is crucial for restoring teeth badly damaged by decay. It involves removing root canal filling material, which can disrupt the apical seal, allowing bacteria and fluid ingress [14, 15]. A 3-5 mm gutta percha seal is preferred [16, 17] while a <3 mm seal is unpredictable [18]. The goal is to create a well-filled root canal with a three-dimensional seal against bacterial colonization [19], with a success rate of 90% in the absence of periapical lesions [20, 21, 22].

Practitioners must consider several factors during post preparation to improve outcomes. These include root canal filling length, post length, crown-to-root ratio, post width to root width ratio, and gaps between the post and gutta percha. Healing is improved when gutta percha is less than 2 mm from the radiographic apex [23,24,15]. A 1:1.5 ratio is considered acceptable for fixed partial denture abutment and a 1:1 ratio for healthy periodontium [25, 26]. Post space preparation should be equal to and exceeding one-third of the root width [27, 28], with conservationists advocating minimal removal of dentin to ensure easy placement without undercuts and preservation of maximum tooth structure [29, 30]. Preservationists advocate for at least 1 mm of dentin surrounding the circumference of a post to prevent root fracture [31]. Gaps between the post and gutta percha also influence the rate of periapical disease development, with larger gaps predisposing to disease at one-year follow-up and a gap >2 mm resulting in periapical disease in 70.6% of cases [32].

The relationship between tooth type and position in the dental arch and the selection of post-and-core systems used in endodontically treated teeth restoration is controversial [33]. Anterior teeth treated with post-and-core restorations have a fracture rate three times higher than posterior teeth [34], partly due to greater horizontal forces present in anterior teeth. Posterior teeth are subjected to a more perpendicular compression force vector [33], which causes fatigue fractures. Therefore, the anterior region of the maxilla can be considered an area of high fracture risk. [33, 34]

Mishaps during the post and core workflow are common, , Zahran M et al [35] reported 28.5 % incidence related to post placement. About 33% of these incidences were during gutta-percha removal, while 30% were during drilling using different posts systems, 30% were during post cementation, and 7% during impression making for the post. Strip perforation was the most common complication reported for 33% of the cases. Maxillary teeth (64%) were mostly affected teeth by mishaps Preparation of a post space adds a certain degree of risk to a restoration procedure. Procedural accidents in the form of perforation can occur. The placement of posts also may increase the chances of root fracture and treatment failure, especially if an oversized post channel is prepared. Hence posts should only be used when other options are not available to retain a core [36,37].

The post length also determines the retention as well as the resistance of the tooth, such as an appropriate length of post mitigates the applied stress on the tooth, which helps in better stress dissemination [38]. Post dislodgment is the most common complication faced according to a ten-year retrospective study [39]. Coronal microleakage is a concern raised by dentists, as inadequately restored teeth may allow root canal filing microorganisms to enter the root canal, stressing a well-sealed restoration to mitigate dormant microorganism reactivation.[40]. Many criteria have been suggested to assess the quality of post and core restorations, mainly based on radiographic evaluation alone or in combination with clinical examination [41,42].

Various parameters affect the prognosis of endodontically treated teeth (ETT), such as final restoration type, post and core material design, remaining tooth structure, and ferrule presence [43]. Post and core have been successfully used to provide adequate support and retention, but several cases of failure have been reported [44]. Hence, the aim of this study was to assess the prevalence of mishaps and the most critical errors encountered in post and core procedures. In addition to report and analyze failures of post retained restorations to identify factors critical to failure and to the type of failure.

2.Materials and Method

A cross-sectional study was conducted in several private dental clinics in Benghazi, Libya. A total of 300 root canal treated teeth restored with posts and cores were examined clinically and radiographically using a digital periapical radiograph to evaluate the quality of these restored teeth. Radiographs were evaluated by a fixed prosthodontist and an experienced teaching staff member in the university. Radiograph quality was assessed as adequate or less than adequate according to the presence or absence of cone cutting, overlapping, elongation, or shortening; however, these features did not affect the formal measurements of quality of root canal treatment. The radiographic images were saved in a file and identified with numbers to maintain the confidentiality of the patient’s identity. Clinical examination was done using an explorer, periodontal probe, and mouth mirror. Moreover, patients were investigated about any symptoms and signs like pain, pain on percussion, swelling, discomfort, pus discharge, or bleeding related to the tooth of interest. Post and core-treatment quality was assessed by the investigator according to previously published criteria [11,45,46] (Table 1). Any radiographic or clinical sign of failure was recorded and classified according to Singh SV and Chandra A classification system [44] (Table 2.). No distinction between age and gender of patients was considered. To avoid bias, all the subjects of this study were not treated by the researcher. All the data were collected and recorded in an Excel sheet for analysis.

Statistical analysis

The obtained data was compiled in a computer and analyzed using Statistical Package for Social Science (SPSS v.23). The frequency distribution for all variables was calculated and the percentages of the identified categories were obtained. To estimate the potential association between nominal variables, the Chi-square or Fisher's exact tests were applied. The Phi coefficient test was performed to measure the strength of the association between two nominal variables. The Phi coefficient ranges from −1 to +1, with negative numbers representing negative relationships, zero representing no relationship, and positive numbers representing positive relationships.

Table 1: Assessment criteria and guidelines for post and core treatment quality

Post and core with ideal criteria • Yes • No
Root Canal Treatment quality: • Good • Poor
Tooth type • Anterior • Posterior
Tooth location • Maxillary • Mandibular
Type of final restoration: • Single tooth restored with single crown • Abutment tooth for a bridge
Type of post: • Ready-made metal post • Ready-made fiber post • Custom made metal post • Custom made zirconia post
Post length: • Equal 2/3 to the root length • More than 2/3 of the root length • Less than 2/3 of the root length
Post diameter: • Equal 1/3 to the root width • More than 1/3 of the root width • Less than 1/3 of the root width
Remaining guttapercha length apically (apical seal) • Between 3-5 mm • More than 5mm • Less than 5 mm
Gap between post and guttapercha more than 2 mm • Yes • No

Table 2: Classification for post and core failure

Classification	Type of failure
Type I	Loosened or dislodged post and core
Type II	Fracture post and core
Type III	Fracture root
Type IV	Root perforation caused by post
Type V	Post and core failures because of caries, periapical abscess, or combined

3.Results

Overall, the method of tooth assessment varied among the participants in the study. The majority of participants, 53.3%, relied on radiographic assessment. A smaller percentage, 5.7%, assessed teeth clinically. However, a significant portion, 41%, utilized both clinical and radiographic examination. Of the 300 endodontically restored teeth that were examined, 23.7% had met the ideal criteria, while 76.3% were not restored properly. (Figure 1)

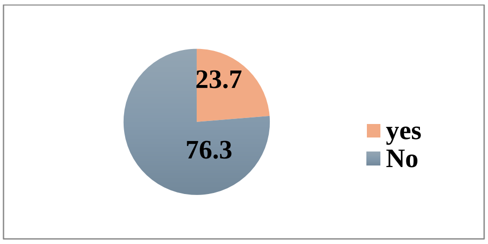

Figure 1: Post and core with ideal criteria.

The distribution of tooth types in the study sample is quite varied, with a majority of cases involving upper anterior teeth (35.3%) and upper premolars (30%). Lower anterior teeth made up a small percentage of cases (2%). The evaluation parameters of the included posts in the study focused on the quality of root canal treatments, with 48.3% of cases deemed to be of poor quality and 45.7% considered good.

In terms of post selection, it appears that the majority of evaluated samples were restored with ready-made metal posts (70.3%). Following closely behind are custom-made metal posts (20.7%). Ready-made fiber posts are used in 7%, while custom-made zirconia posts are the least popular choice, with only 2%. Regarding the post length and diameter, the data showed that a majority of the posts (64%) were less than 2/3 of the root length (Figure.2), and most of the posts in the study had a diameter that is equal to one third of the root width (66.7%)

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In relation to the apical seal for the root canal treated teeth, the majority had more than 5 mm of gutta percha present, with 54.3% falling into this category. Additionally, (33%) of the teeth had between 3-5mm of gutta percha, while only (7%) had less than 5mm present. There were 17.3% of the examined teeth that revealed a 2mm or more gap between the gutta percha and the post.

The study also found that the vast majority of the post and core were for single teeth restored with a single crown (85%), with only opting for (15%) as abutment teeth in bridges.

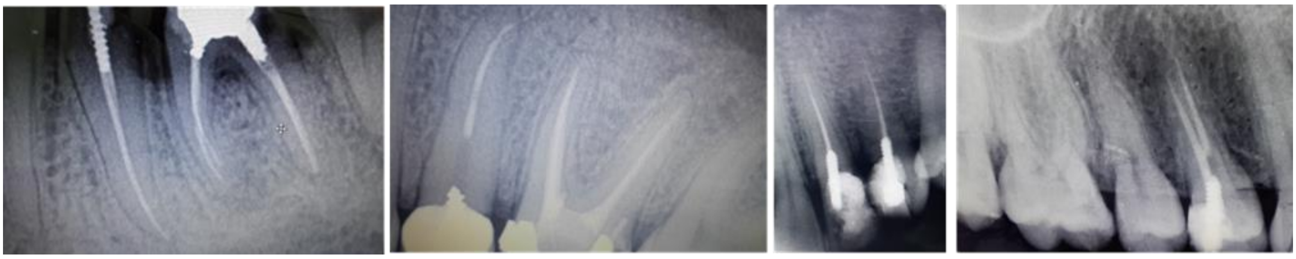

Figure 2: Radiographic examination showed most of the subjects restored with short posts

The results of the study showed a significant relationship between endodontic and post-mishaps and the different tooth groups. Specifically, a significant difference in the occurrence of post-failures based on the type of tooth. The highest percentage of poor RCT quality was seen in the upper molars, followed closely by the lower molars. There was a statistically significant difference in the gap between the post and gutta-percha among the upper anterior teeth and upper premolars. However, it is interesting to note that the highest percentage of ideal post occurred in the upper anterior 31.1% and the upper premolar group at 17.8%, while the lowest percentage occurred in the lower anterior group at 16.7%. There was no significant difference. The failure in this study was classified according to Singh SV and Chandra A classification system.[44] (Figure. 3)

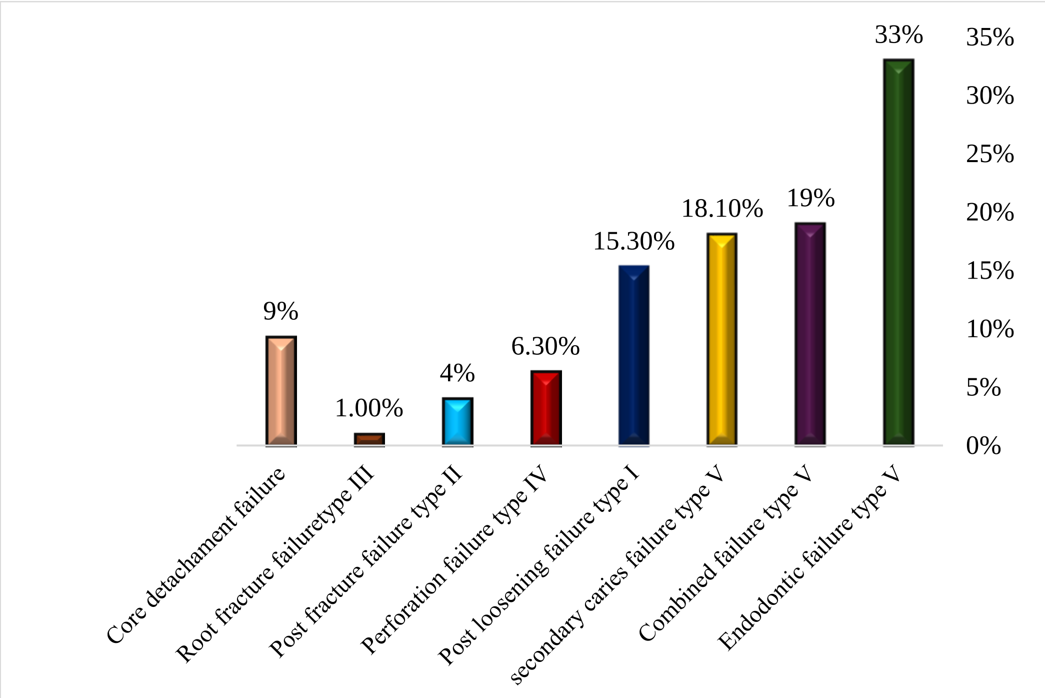

Figure 3: Classification and percentage of post and core failure

The data suggests that there were only 3 cases of type III failure (Figure. 4.A) in the upper anterior teeth group. The highest rate of type II failure is associated with upper premolars at 2.2%, followed by lower molars at 3%. Interestingly, there was no type II failures (Figure 4.B) reported in the lower anterior teeth group. There was no significant relationship. Type I failure (Figure 4.C) was most common in the upper anterior group, followed by the upper premolar group. The lower molar group had the lowest incidence of type I failure. There is a significant relationship ($P<0.05$). There was no significant difference in the rate of core detachment failure between the different tooth groups (Figure 4.D). However, it is worth noting that premolars in both the upper and lower arch had a slightly higher incidence of mishaps compared to anterior and molar teeth. The results of the study show that the rate of endodontic and post-failure type V varies across different tooth groups (Figure 4.E). Interestingly, upper and lower premolars had the highest rates of failure compared to anterior and molar teeth. According to the data, 81% of participants had no combined failure, while 19% reported experiencing type V combined failure (Figure 4.F)

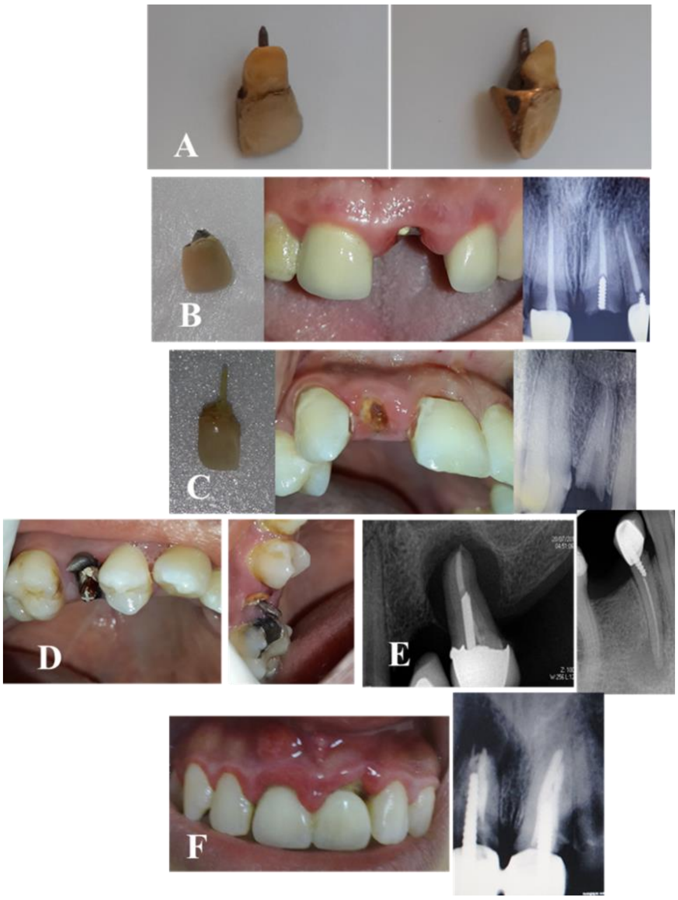

Figure 4: Types of failure

A. Type III failure (Root fracture)
B. Type II failure (Post fracture)
C. Type I failure (Post loosening or debonding)
D. Core detachment failure
E. Type V failure (Endodontic failure)
F. Type V failure (combined failure)

Overall, type IV (perforation) failure was found to be more common in the upper anterior teeth compared to the lower anterior teeth (Figure 5). However, there was no significant difference between upper premolars and molars, as well as lower premolars and molars (P value = 0.071).

Figure 5: Type IV failure (Perforation failure)

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A. Root perforations of upper left premolars restored with ready-made metal post
B. Root perforation of upper left central incisor restored with fiber post
C. Root perforation of upper left central incisor restored with custom made metal post

Table 3: Type of failure in relation to post and core system

Type of failure	Crosstab						
	Type of post and core				Total	P value	Phi
	Ready-made metal post	Ready-made fiber post	Custom made metal post	Custom made zirconia post			
Type I failure (Loosened post)	(14.7%)31	(9.5%)2	(21%)13	0	(15.3%)46	0.360	0.104
Type II failure (Fractured post)	(4.7%)10	(4.8%)1	(1.6%)1	0	(4%)12	0.682	0.071
Type III failure (Root fracture)	0	0	(4.8%)3	0	(1%)3	**0.009**	0.197*
Type IV failure (Perforation)	9 (4.3%)	2 (9.5%)	8 (12.9%)	0	19 (6.3%)	0.079	0.151
Type V failure (Endodontic failure)	(40.3%)85	(23.8%)5	(14.5%)9	0	(33%)99	**<0.001**	0.248*
Type V failure (Secondary caries)	44 (20.9%)	4 (19%)	6 (9.8%)	0	54 (18.1%)	0.155	0.132
Type V failure (Combined failure)	46 (21.8%)	4 (19.0%)	7 (11.3%)	0	57 (19%)	0.181	0.128
Core detachment failure	(13.3%)28	0	0	0	(9.3%)28	**0.005**	0.208*

The crosstab data revealed that 21.8% of teeth that were restored with ready-made metal posts experienced type V combined failure, while only 19.0% of those restored with ready-made fiber posts reported the same. Additionally, 11.3% of samples treated with custom-made metal posts experienced combined failure, while none of those using custom-made zirconia posts reported any combined failure. The P value of 0.181 indicates that there is no significant relationship between the type of post and the occurrence of combined failure. The majority of type V secondary failures occurred with ready-made metal posts at 20.9%, followed by ready-made fiber posts at 19%. Custom-made metal posts had a failure rate of 9.8%, while custom-made zirconia posts had no reported failures. The P value of 0.155 indicates that there is no significant difference in failure rates between the different types of posts. The Phi value of 0.132 also suggests a weak association between the type of post and the occurrence of failure. (Table 3)

The data also showed that the type of failure varied depending on the type of post used. Among samples that were treated with ready-made metal posts, 4.3% reported type IV failure, while 9.5% of those restored with ready-made fiber posts reported type IV failure. In comparison, 12.9% of teeth treated with custom-made metal posts experienced type IV failure (Figure 6.A). Interestingly, none of the samples that were treated with custom-made zirconia posts reported any failure. The P value for this data is 0.079, indicating a moderate level of significance. Ready-made metal and fiber posts, in addition to custom-made zirconia posts, had the lowest incidence of type III failure (0%). In contrast, custom-made metal posts had the highest rate of root fracture failure at 4.8% (Figure 6.B). The P value of 0.009 indicates a significant relationship between the type of post used and the occurrence of type III failure. And there was a weak positive correlation between the post type and type III failure. The data also showed that there were no significant differences in type II failure based on the type of post used. The majority of post fracture failures occurred in the category of ready-made metal posts, with a failure rate of 4.7%, followed by ready-made fiber posts at 4.8% (Figure 6.C). Custom made metal and zirconia posts had lower failure rates at 1.6% and 0%, respectively. Overall, the results suggest that the type of post used did not have a significant impact on the occurrence of type II failure in the study samples.

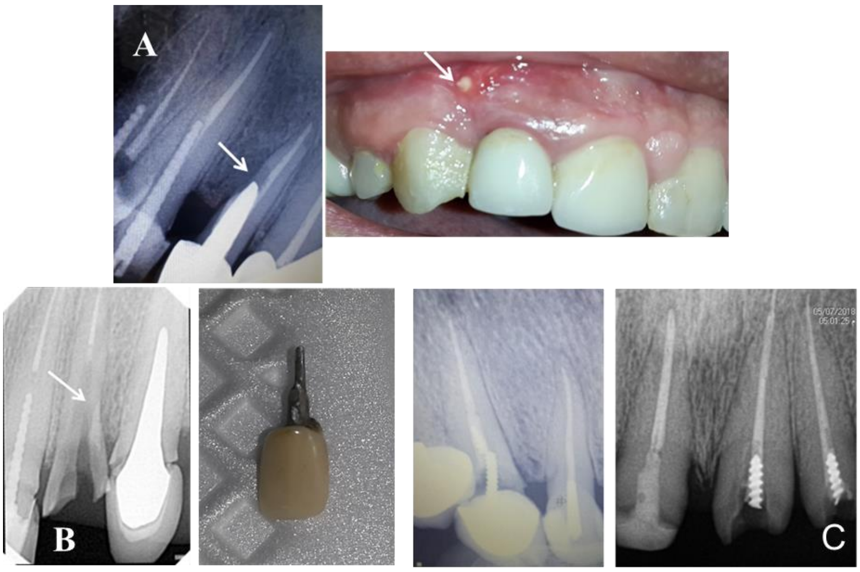

Figure 6: Type of failure depending on the type of post used

A. Type IV failure (perforation) in tooth restored with custom metal post
B. Type III failure (root fracture) for upper left lateral incisor restored with custom metal post
C. Type II failure (post fracture) for upper anterior teeth restored with ready-made metal post

Type V (endodontic) failure was more likely to be with ready-made metal posts (40.3%). The difference in type of post used between those who experienced type V (endodontic failure) and those who did not was statistically significant with a p value of less than 0.001. and a weak positive correlation (Phi= 0.248) (Table 3). The data showed that there is a significant difference in the core detachment failure based on the type of post used. Teeth restored by using ready-made metal posts had a failure rate of 13.3%. There were no reported failures for custom-made metal or zirconia posts. With a weak positive correlation (Phi= 208) (Table 3). Overall, the data suggested that the majority of samples did not show type I failure. When looking at the type of failure and post used, there is no significant difference in the rates of post loosening failure between different types of posts. This indicates that the type of post used may not have a significant impact on the likelihood of experiencing debonding failure (Table 3).

This study found a significant correlation between the gap between the post and gutta-percha exceeding 2 mm and endodontic failure. The data showed that 32.8% of cases with a gap greater than 2 mm experienced endodontic failure (Figure 7.A), compared to only 67.2% of cases with a smaller gap. This suggests that a larger gap between the post and gutta-percha may be a risk factor for endodontic failure.

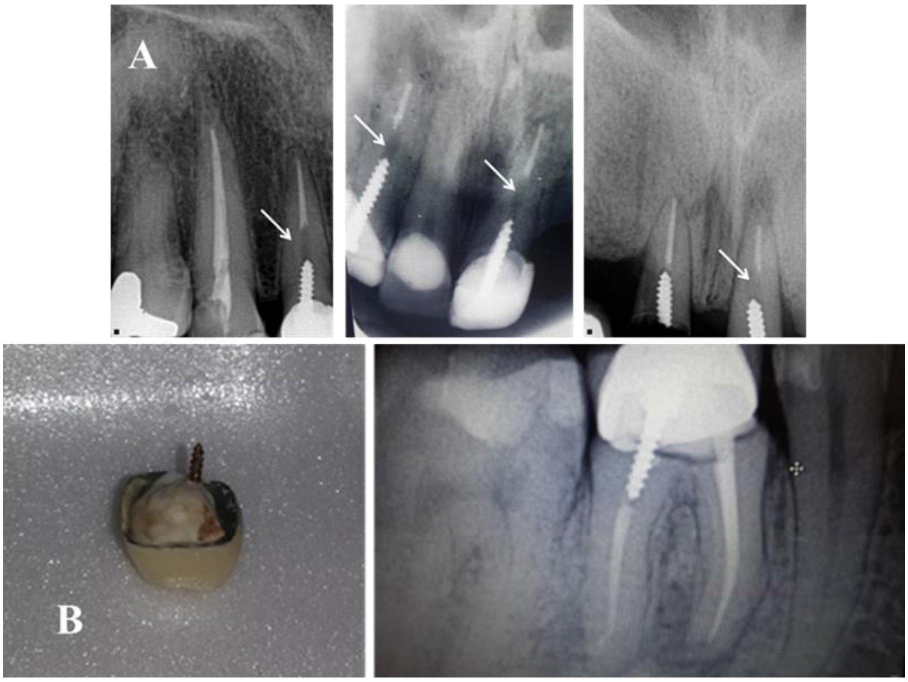

Figure 7

A. Correlation between the gap between the post and gutta-percha exceeding 2 mm and endodontic failure

B. Type I failure (post debonding) associated with short post

Table 4: Correlation between the tooth location and post-cores with ideal criteria

	Post and core with ideal criteria * Tooth location Crosstabulation							
	Tooth location							Phi
	Upper anterior	Lower anterior	Upper premolar	Lower premolar	Upper molar	Lower molar	P value	
No	68(30.4%)	5(2.2%)	74 (33%)	29 (12.9%)	22 (9.8%)	26 (11.6%)	0.098	0.231
Yes	33(46.5%)	1(1.4%)	16 (22.5%)	9 (12.7%)	5 (7%)	7 (9.9%)		
Total	106(35.3%)	6(2%)	90 (30%)	38 (12.7%)	27 (9%)	33 (11%)		

As shown in table 4, the results of the crosstabulation analysis indicate that there is a statistically significant relationship between tooth location and the ideally restored endodontically treated teeth. Specifically, a higher percentage of cases with ideal post and core were found in the upper anterior and upper premolar teeth compared to the lower anterior, lower premolar, upper molar, and lower molar teeth.

Correlation between post length and post debonding failure

The data of this study suggests that there is a significant relationship between post length and failure rates. Specifically, posts that are less than 2/3 of the total length of the root are associated with a higher rate of failure, with 59.4% of cases resulting in type I failure (Figure 7.B). On the other hand, posts that are equal to or greater than 2/3 of the total root length have a lower failure rate, with only 1.6% of cases resulting in failure. This relationship is statistically significant with a p value of 0.001 and a Phi coefficient of 0.230.

Regarding the post and core type in relation to the tooth location and the data presented, it is clear that ready-made metal posts are most commonly used in upper premolar teeth, with 32.7% of cases, while custom-made zirconia posts are only used in upper anterior teeth. Ready-made fiber posts are most frequently utilized in upper anterior teeth, with 57.1% of cases. Custom-made metal posts show a more even distribution among tooth locations, with 50% used in upper anterior teeth and 27.4% in upper premolar teeth. Overall, the choice of post and core material seems to vary based on the location of the tooth requiring treatment.

In general, the average success of the restored endodontically treated teeth was 62%, whereas the failure was 38%. Overall, the data shows that the failure rate is highest in the upper anterior teeth, followed closely by the upper premolars. Lower anterior and lower premolars have the lowest failure rates. Interestingly, the failure rate in lower molars is higher than in upper molars. (Figure .8)

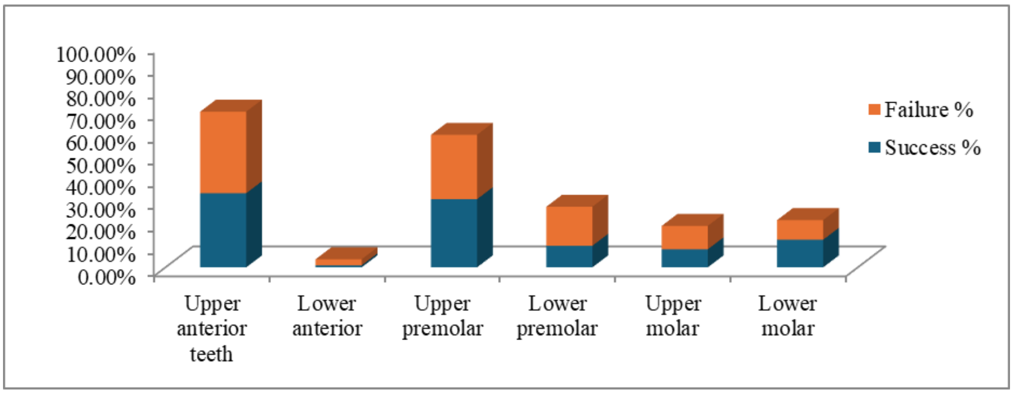

Figure 8: Correlation of failure rate and tooth location

The data showed that the failure rate for single tooth restorations with a single crown (59.6%) is less when compared to a restored tooth used as an abutment tooth for a bridge, which has a failure rate of 75.5% (Figure 9). This suggests that an endodontically treated tooth restored with a single crown may be a more successful treatment option in terms of longevity and durability. It is important for dental professionals to consider these findings when planning and executing restorative treatments for their patients.

Figure 9: (A and B) Failed cases in which the restored teeth were used as abutment in fixed partial denture

4.Discussion

Because of the significant loss of tooth structure brought on by the removal of a carious lesion, crown fracture, and access for endodontic treatment, teeth that have had endodontic treatment need extra attention when they are prosthetically restored. Posts and cores should be used as part of treatment when there is significant coronary destruction and the remaining dental material is insufficient to provide the filling resistance and structural retention so that the crown can be rebuilt. [47,48].

Clinical and radiographic examinations were used in this study to evaluate the restored endodontically treated teeth. Bonfante et al. state that in order to evaluate dental remnant conditions, a clinical and radiographic analysis is required. This analysis should take into account the tooth's periapex and root bony implantation, as well as the amount of dental remnant that remains after carious tissue and existing restorations have been removed. [49].

Periapical status, tooth position, number of neighboring teeth, occlusal contacts, remaining tooth structure, collagen degradation and intermolecular cross-linking of the root dentin, type of coronal restoration, type of post (if required), and core material used are some of the several factors that affect the prognosis of endodontically treated teeth [50]. Numerous studies back up the theory that fractures in teeth treated with root canals are more likely to occur than in vital teeth because of changes in structural integrity related to site preparation and preexisting tooth defects [51,52] rather than physical or chemical changes in the tooth tissue [53,54]. In a tooth with significant loss of coronal structure, a post is typically inserted to retain the core [55]. The remaining tooth structure and surrounding alveolar bone provide the tooth's strength and fracture resistance; post-placement procedure does not reinforce or strengthen the tooth. [56]

Maintaining healthy periradicular tissue and the tooth's functionality without causing pain to the patient is the primary objective of endodontic treatment. [57]. The study's findings indicated that, with regard to the quality of root canal therapy as one of the primary factors to be taken into account when recovering teeth that have had endodontic treatment, 45.7% of instances were judged to be of high quality and 48.3% to be of poor quality. Voids, inadequate canal preparation, lack of lateral condensation, short filling, overextended obturation, or a combination of these were blamed for the poor quality. This contrasted with findings published by Baik KM, which showed that 63% of the evaluated teeth had high-quality root canal therapy [58].

Preoperative periapical diagnosis and operative factors, including the use of rubber dam, endodontic mishaps, the technical quality of the obturation, and postoperative coronal restorations, have been shown to affect the outcome of endodontic treatment [21,59,60,15,61,62]. The goal of technological advancements like engine-driven files is to enhance the technical quality of root fillings and raise RCT's success rate [62] Following an RCT, a successful outcome is frequently determined by the radiographic absence or reduction of periapical lesions, the absence of clinical signs or symptoms, and the absence of patient discomfort. A well-executed endodontic treatment is thought to result in more careful prosthesis execution, confirming that this is a fundamental requirement for starting the prosthetic stage preparation. These two phases are interdependent and must be carried out correctly to achieve success [45].

The outcome of post and core restorations is dependent on accurate diagnosis, treatment planning, and perfect execution of each step of that plan. In order to evaluate the treatment method, the assessment must be carried out as follows: prior to post-insertion, following cementation, during follow-up after teeth are exposed to masticatory loading forces, monitoring during maintenance recall, and checking the root canal treatment (RCT) system seal [63,64].

A number of factors, including the material of the used post, post length in relation to tooth length, and post preparation dimensions in relation to tooth dimensions, affect the success and longevity of post and core restorations.[65]

Post success was defined according to the following criteria: between 3 and 5 mm gutta percha remaining; absence of a gap between the most apical part of the post and the most coronal part of the gutta percha or presence of a small gap of up to 1 mm; a post width of no more than one-third of the root width; and post length should be two third of the root length or at least same as the length of the final crown [66, 67].

According to the study's findings, only 23.7% of the posts fulfilled the ideal requirements. This was consistent with a study by Almaghrabi J et al. [66], which found that 11% of the posts satisfied every ideal prosthetics criterion. However, he also reported that the majority of post and core restoration qualities were clinically acceptable. The quality of posts in other studies was 97.5% [58] and 98% [68], respectively, showing good radiographic quality and post space preparation.

There is ongoing discussion regarding the ideal post length; some research indicates that a longer post is more fracture-resistant, while other research suggests that there is no relationship between post length and fracture resistance [69]. Some reports have recommended a post length of three-quarters of the root length or at least half the crown length [70], others have reported a 97% success rate if the post equals the crown length [71], while still others have reported that the minimum post length should be 8 mm [72]. Since mechanical stress during mastication is known to concentrate at the alveolar crest, it has been proposed that the post should always extend beyond the alveolar crest [73].

The data of this study revealed that, the majority (64%) of the assessed posts were short and less than two third of the root length. This was significantly different from a study performed by **Meshni et al** [11], who found that the post to root length ratio in 58% of patients was 2:1, and in 51% was 1:1. Similarly **Almaghrabi J et al [**66] showed that post length was less than 2/3 of the root length in 61% of cases.

For **Johnson et al [**29], the longer and wider the posts, the greater their resistance and retention, but not in excess to avoid weakening the root due to excessive wear. **Mattison et**

al [16] recommended that the length should be as long as possible, however 5 mm of the apical seal must be maintained at the tooth apex to prevent reinfection of the previously treated canal. **Shillingburg and Kessler** [25] stated that the length of the post inside the canal must be equal to or greater than that of the crown, or two-thirds the length of the root to achieve maximum retention. For these authors [25], short posts provide less retention and can cause root fractures.

There are different viewpoints on the ideal post width in relation to the root width. Some advocate preparing the post space to be at least one-third of the root width, while others advocate removing as minimal dentin as possible to ensure easy post placement without undercuts and to preserve as much tooth structure as possible. At least 1 mm of dentin should be preserved around the post circumference to prevent root fracture. [29].

The study findings showed the majority (66.7%) have a diameter that is equal to one third of the root width. This was in contrast to **Alshehri T et al [**68] who showed 31.9% of the cases were treated with post diameter equivalent to 1/3 of the root diameter. A study conducted at Qassim university dental clinic was in line with this study findings and showed 81% of the post cases were of diameter equal to 1/3 of the root [46].

Regarding retention, there appears to be general agreement that increasing post diameter is not a reliable way to increase retention [74]. According to a study using finite element analysis, increasing the post diameter resulted in less stress formation in the dentin [75]. There appears to be general agreement that the root canal shouldn't be unnecessarily enlarged because doing so weakens the tooth and lowers its resistance to fracture [75–77].

To preserve apical integrity and a suitable apical seal, the length of Gutta Percha that must remain apical to the end of posts should be between 3 and 4 mm or 3 and 5 mm [78-80] In this context, 33% of assessed endodontically treated teeth (ETT) in this study featured 3 to 5 mm of gutta percha (GP), and 54.3% presented more than 5 mm. This was in coincidence with **Alshehri T et al [**68] who found 38.8% of the cases with gutta percha of 3-5mm left apically, while 61% of cases included more than 5mm of remaining GP. Similarly, a study done by **Mathar and Almutairi [**46] found 28% of the assessed cases had 3-5 mm of remaining GP and 61% included more than 5 mm of remaining GP, although they considered the qualities of the assessed posts were clinically acceptable. In contrast to this, a study performed by **Baik KM [**58] showed **t**he observed remaining amount of GP was 3–5 mm in 55% and more than 5 mm in 29% of cases, this was Comparable to the study of **Meshni AA et al [**11] who explained their results considered excellent because 70% of the cases were restored with glass fiber posts. **Baik KM [**58] stated that placing posts in posterior teeth is determined by the root anatomy, and when the root tapers apically or is severely curved, dentists tend to stop before the curvature to avoid perforation or stripping. But this was not the case in this study, as the majority of the examined teeth were upper anterior, and most of the posts were metal. When roots are long the dentist must stop early to leave a coronal segment to retain the core. Therefore, it is acceptable to leave more than 5 mm of gutta percha if the post is at least half the length of the root, which was not the case in this study.

The presence of a gap between the most apical part of a post and the most coronal part of the gutta percha is common and creates a habitat for microorganisms [81]. Gaps may negatively influence microleakage [82], with increased microleakage observed with a gap of 2–3 mm between the post and the gutta percha compared with either a gap refill with gutta percha or the absence of a gap. The data of this study showed 17.3% of the examined teeth reveal 2mm gap or more whereas 82.7% of the cases have no gap. This result was in agreement with **Alshehri T et al [**68]**, Almaghrabi J et al [**66]**,** and **Mathar** and **Almutairi [**46] who demonstrated that most of the restored teeth 95.6%, 93%, 82.9% showed no gap between the cemented post and GP, respectively. In contrast, **Baik KM [**58] revealed that only 65% of treated cases had no gap between post and GP. **Moshonov J et al [**81] affirmed that the gap size may influence the rate of periapical disease development, with larger gaps having a higher rate of disease at one-year follow-up. In addition, a gap >2 mm can cause disease in the periapical area in over two-thirds of cases.

To restore teeth that have undergone endodontic treatment, a variety of materials and methods are employed. In the past, the most widely used post and core system was cast post and core [83,84]. The gold standard post system for restoring severely damaged endodontically treated teeth is still cast post and core [85,86]. Custom-fabricated post and cores using a standardized fabrication technique have shown a good long-term prognosis with an average survival time of 7.3 years [87]. Despite its widespread use, cast post and core still has a number of drawbacks, including dislodgment, periapical lesions, and root fractures [88]. On the other hand, they do offer some advantages. In the cases of severely distracted teeth the one-piece post and core system avoids potential core delamination by eliminating interfaces between the post and the core as mentioned by **Bittner N et al [**89]. **Nandini VV** and **Venkatesh V [**90] advocated when multiple teeth require posts it is more efficient to make an impression and fabricate them in the laboratory rather than placing a post and build up in individual teeth as a chair side procedure. Multiple in vivo studies concluded low success rate and higher failure for cast post and core such as in **Ferrari et al in 1995**, who found that cast post and core showed high percentage of failure 14% and low success rate 84% 88. In 2007 found that failure rates of 8.82% were observed in the cast metal post after 4 years of clinical service [91]. Another study of **GA Preethi et al**. found that the success rate of the cast post and core was 90% after only one year [92].

Prefabricated metallic posts are made of stainless steel, nickel chromium alloy, or titanium alloy. They are all very rigid except titanium. They are round and offer little resistance to rotational forces. Hence, they should be used only when adequate tooth structure remains. Bonded material must be used as core [90].

Through the translucent all-ceramic crowns, metal posts are visible; they could give the marginal gingival a dark appearance. This led to the development of aesthetic posts made of zirconium and other ceramic materials. They have the drawback of requiring to be thicker in order to be stronger, despite their good aesthetics. Since zirconium posts cannot be etched, bonding a composite core to a post is not feasible. Zirconium and ceramic posts are very hard to retrieve. Some ceramic materials can be eliminated by using a bur to grind away the leftover post material, but this is a time-consuming and risky process. [90].

Prefabricated fiber posts are roughly the same stiffness (modulus of elasticity) as dentin and are more flexible than metal. They evenly distribute forces in the root when bonded with resin cement, which reduces the likelihood of root fractures. They are comparatively simple to remove and radiolucent. [90]. conversely cast posts, zirconia posts, or prefabricated metal posts are more rigid (higher modulus of elasticity) than dentin, and may increase the risk of unfavorable failures, that's why Fiber posts are an alternative since they have mechanical properties similar to the dental structure and so generate a more uniform stress distribution to the root, reducing the risk of catastrophic failure. This dilemma is still a big concern in dentistry, and there is conflicting evidence about the best kind of post to restore pulpless teeth.[93] Thus, today's conundrum would be determining which material, or combination of materials, is the most effective in terms of strength and reliability, aesthetics, and manipulation ease [5].

According to this study, 70.3% of the evaluated teeth were restored with prefabricated metal posts, followed by custom made metal posts 20.7%, then 7% fiber posts, and only 2% for custom made zirconia posts. Selection of the most suitable post and core system is challenging, and a number of different techniques and materials are used for this purpose in clinical practice. According to the study's findings, metallic posts were used to treat the majority of the evaluated teeth; this could indicate that metallic posts have been clinically employed in dentistry for a longer time.

In terms of the tooth type distribution in this study, the majority of cases were upper anterior teeth, followed by upper premolars, while a small percentage of cases were lower anterior teeth. These variations suggest that both function and appearance are powerful motivating factors behind dental care. Results of the present study revealed that posts are more frequently used in maxillary than in mandibular teeth. These results support some previously reported findings by **Jamani et al [**78] and **Al-Hamad et al [**79], who showed that the most frequently restored teeth with posts and cores were, incisors followed by premolars. Their findings also reflect their desire to save damaged teeth.

The results of the study showed a strong relationship between endodontic and post-mishap issues and the different tooth groups. The upper molars exhibited the highest percentage of poor RCT quality, with the lower molars following closely behind. This was in contrast to **Balkenhol et al [**87] who concluded that neither the type (anterior, posterior) nor the location (upper or lower jaw) of the tooth affect the success probability of the restoration.

According to the data, a greater percentage of cases with ideal post and core were found in the upper anterior and upper premolar teeth, which demonstrated a relationship between tooth location and post-cores with ideal criteria. It is evident from the data that custom-made zirconia posts are only used in upper anterior teeth, whereas ready-made metal posts are most frequently used in upper premolar teeth. The majority of the upper anterior teeth are restored with ready-made fiber posts; custom made metal posts showed a more even distribution among tooth locations. Overall, it appears that the location of the tooth that needs to be treated influences the choice of post and core material.

According to the data as a whole, the upper anterior teeth have the highest failure rate, closely followed by the upper premolars. The lowest failure rates are found in lower anterior and lower premolar teeth. It's interesting to note that lower molar failure rates are higher than upper molar rates. These failures are generally related to occlusal forces. A higher incidence of horizontal forces responsible for tensile and shear stresses occurs in anterior teeth [94,33] which, along with the premolars, are subjected to lateral forces [95]. In molars, vertical compression forces are more frequent. [33,95] However, some studies reported a higher frequency of fractures in posterior teeth [95,96]. This result can be explained by the absence of remaining walls on the treated teeth.

Different failure rates have been reported for post retained restorations in various clinical trials. In the current study the average percentage of failure was 38% and average percentage of success was 62%. According to **Singh SV** and **Chandra A [**44] classification system, the most common type of failure in this study was (type V) which is biological failure caused by failed root endodontic treatment 33%, caries 18.1%, or combined (19%) followed by (type I) debonding or loosening of the post 15.3%, (type IV) root perforation 6.3%, (type II) post fracture 4%, and finally (type III) root fracture 1%. Other type of failure was revealed in this study but was not included in the previously mentioned classification is core detachment from the post 9.3%.

Clinically, the mode of failure is an important factor to assess in addition to the restoration's survival because it dictates whether the tooth can be fixed and continue to function. The majority of the failures that result in loss of retention can be repaired, but tooth fractures are typically irreparable and require extraction. Regarding endodontic failure many factors could have resulted in it, but these factors are not studied in the present study. One of the suggested causes can be due to the improper case selection and treatment planning errors as shown in **Sarkis et al [**96] One of the most influential and determining factors for the success of endodontic therapy is whether a periapical injury exists former to practice [15,97-99].

This study found that a gap greater than 2 mm between the post and gutta-percha was strongly associated with endodontic failure. Data showed that endodontic failure occurred in 32.8% of cases with a gap greater than 2 mm. This suggests that a larger gap between the post and gutta-percha may increase the risk of endodontic failure.

Since loss of retention is still a common form of failure, clinicians ought to think about implementing extra steps to optimize post-tooth retention. Among these tactics are ferrules. The ferrule effect is crucial to the survival of endodontically treated teeth with posts, particularly when there is significant damage to the remaining hard dental tissue. It is best to provide this effect with careful preparation or through alternative methods, such as orthodontic extrusion or surgical crown lengthening [100-105]. In fact, according to **Creugers** [106], the amount of remaining dentin height after preparation positively influences the longevity of the post-and core restoration.

Adhesive luting of fiber posts has been proved to increase their performance and biomechanical properties (fracture resistance, higher bond quality with tooth structure) [60, 73, 74], but no data exists to support the same hypothesis for metal posts. Posts that are shorter than the recommended length may generate forces off the tooth fulcrum and cause displacement through improper retention, increasing the risk of root fracture due to second-degree lever behavior. The length of the post affects the retention of the post, core, and crown. The preservation of the restoration increases with increasing apical length of the post inside the root canal [107]. There have been many reports of a correlation between the post's length and the endodontically treated teeth's resistance to fracture [107,108]. An excessively long or short post could put the root at risk of breaking.

According to the study's data, failure rates and post length are significantly correlated. In particular, a higher rate of post loosening is linked to posts that are less than two-thirds of the root's overall length. Conversely, the failure rate is lower for posts that are at least two thirds of the total root length. Some drawbacks to post space preparation include perforations in the apical or lateral regions of the root (strip perforation) [36]. Root perforation results in the communication between root canal walls and periodontal space (external tooth surface). It is commonly caused by an operative procedural accident or pathological alteration [109].

This study's use of an intraoral periapical radiograph system, which produces two-dimensional representations that prevent an accurate four-dimensional assessment of the case, is one of its limitations. For the diagnosis and prognosis of this clinical condition, cone-beam computed tomography is a valuable tool [109].

The prognosis of teeth with root canal therapy is adversely affected by perforations [110]. Healing does not take place when a traumatic perforation is compounded with a bacterial infection and/or irritative restorative material [111]. The prognosis for treatment is uncertain once an infectious process has started at a perforation site that may have gone unnoticed, and complications could be severe enough to necessitate an extraction [112]. This was consistent with the study's findings because every perforated tooth that was evaluated was inoperable and indicated for extraction. The percentage of perforation in this study was 6.3% which was in agreement with **Sarao et al** who stated the occurrence of perforation in the studies analyzed ranged from 0.6% to 17.6%. The most common factors associated with perforation included experience of the practitioner, type of tooth and morphology of the tooth [113]. **Sarao et al** advised that educational efforts in dental schools should address the issue of perforations and provide more clinical experience prior to graduation in order to improve the clinical skills of graduates.

Regarding the post fracture failure, the majority occurred in the category of ready-made fiber and metal post equally, cast metal had lower failure rate 1.6% whereas custom zirconia post 0%. All of the fractured ready-made metal posts were of active geometry. According to **Novias VR et al [**114], the purpose of posts with macro retentions is to improve the mechanical retention between the post and resin cement. However, because the actual post diameter is reduced, these retentions significantly lower the post flexural strength. The low stiffness and surface geometry (serrations) of fiber posts were cited as reasons for their fracture. Failures in the form of loss of retention are most often restorable, whereas tooth fractures are most often non restorable and lead to extraction of the tooth. According to the study's data, 1% of the roots were fractured. Since none of the participants reported experiencing root fracture with ready-made metal posts, fiber posts, or custom-made zirconia posts, the study's data indicated that these post types had the lowest incidence of root fracture. Conversely, the highest failure rate (4.8%) was experienced by custom-made metal posts. Numerous studies have demonstrated that the majority of fracture patterns are typically undesirable when they arise when the tooth structure is fractured and the cast post and core are used. 115. In addition, **Abduljabbar T et al**. [116] concluded that 90% of fracture patterns of teeth restored with cast post and core were unfavorable (i.e. tooth is not restorable) [116]. In the same topic a study was done by **Salameh Z et al**. [117] concluded that, with a percentage of over 50% of the study sample, teeth restored with cast post and core were substantially more likely to experience an adverse irreparable fracture. A clinical study performed by **Zicari et al** [118] compared the 3-year behavior of teeth treated with glass-fiber posts and composite resin cores versus cast metal posts and cores, and they concluded that both treatments behaved similarly.

Since it has a direct impact on the biomechanical behavior of the restorations, the elastic modulus of the materials used to make the posts is always taken into account. Although more uniform stress distributions in the root canal and improved retention of the coronal restoration can result from stiffer posts and cores, overloading the tooth can cause catastrophic root fractures. Conversely, less rigid posts are susceptible to bending under heavy loads, which can result in the loss of post or restoration retention or even post fracture, which would prevent root fracture. Furthermore, more flexible posts would weaken the cement layer, increasing the risk of secondary caries or canal reinfection and allowing leakage into the restoration margins. [8]. Custom-made CAD/CAM one-piece fiber-reinforced composite post and core have recently been used to restore endodontically treated teeth with extensive loss of coronal structure [119] . This post promotes thinner and more homogeneous cement layer and does not require the construction of a composite resin core build-up. CAD/CAM custom-made posts positively affect bond strength because they generate a thinner cement layer

[120]. Also, the fracture resistance of the fiber reinforced composite milled posts was similar to the cast ones, with a higher percentage of repairable fractures [121]. Another advantage of these systems is that their elastic modulus is closer to the dentin, concentrating less tensile stress on root dentin, reducing the risk of vertical root fracture [122].

PEEK (Polyetheretherketone) is a biocompatible material with low modulus of elasticity that is comparable to dentin tissue, according to numerous studies. It has high shock absorption capabilities and good fracture resistance with adequate stress distribution to the reconstructed tooth. Therefore, a tooth replaced with PEEK post and core material may have higher fracture resistance in theory [123,124]. Moreover, PEEK material is supplied as blanks for CAD/CAM milling. Digital design planning and milling using the digital workflow makes it easier and more dependable to produce custom-made post and core while also saving time [120,125]

Another type of failure found in the present study which was core debonding or detachment from the post in the both groups of ready-made post (fiber and metal), in addition to recurrent caries, the majority occurred with ready-made metal and fiber posts. This finding is in coincidence with other studies who stated that insufficient stiffness will allow excessive distortion of the restoration at the margins during function, leading to breakdown of cement and risk of secondary caries. Moreover, a decrease in the elastic modulus of the post material has been found to increase stress formation in the root and to decrease fracture strength of the restored tooth [75,126-128]**.** Thus, low-modulus posts fail sooner or at lower stress values than do high modulus posts. On the other hand, several studies have found that low-modulus posts display failures that cause little damage to the remaining tooth structure (loss of marginal seal, loss of retention, core fracture, and post fracture), while high-modulus posts are associated with a higher incidence of root fractures when they finally fail; that is, they cause more damage to the remaining tooth structure and often result in the extraction of the tooth involved [126,128-130].

It's interesting to note that the custom-made zirconia post and core group did not exhibit any failures. This could be because only 2% of the evaluated samples were included, or it could be because the posts were treated according to ideal criteria.

The data of the current study showed the failure rate for the assessed endodontically treated teeth (ETT) restored with single crown were 59.6% which is lower than the failure rate of ETT acted as abutment for a bridge 75.5%. This was in accordance to **M. Balkenhol et al [**87] in which the success rate for ETT after six years was 92–94%. Furthermore, the success rate for fixed and removable prostheses was 78% and 66%, respectively. In general, single crowns perform better than other prosthetic restorations [87,71]. This is because the dental stresses in fixed and removable dentures are more than single crowns [87].

Bergman et al. [131] After six years, the success rate of 96 metallic posts and cores was assessed; 90.6% of these treatments were successful, with seven failures in fixed partial dentures. This illustrates how the high functional requirement of posts as abutments for fixed partial dentures raises the risk of failure. Furthermore, **A. Ploumaki et al [132]** claimed that for teeth that have had endodontic treatment, single crowns appear to be the most effective treatment option.

5.Conclusion

The successful post and core treatment relies on multiple factors related to the success of endodontic treatment as well as the procedure and type of post and core placed.

- The most common cause of failure is endodontic failure (biological failure) followed by post loosening (mechanical failure)
- A percentage of 38% is considered unacceptable failure, so this topic should receive special attention in the dental curricula and in designing the continuous education programs to improve the prosthetic and endodontic practices of the practitioners.
- Post length and post loosening are strongly correlated.
- Increasing the gap between post and Gutta Percha is strongly correlated to the endodontic failure.
- High failure rates were noted among endodontically treated teeth restored with cast post and core. This raises a question about the validity of selecting a cast post and core to restore endodontically treated teeth in the presence of other advanced and recent alternative intra-radicular retention systems.

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